# Bacterial WILT of CORN

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BACTERIAL wilt is one of the most destructive diseases of sweet corn. It also may occur on flint, flour, and dent corn and on popcorn. In general, sweet corn is the most susceptible and dent corn the most resistant. Usually the early-maturing varieties of each type of corn are more susceptible than the later-maturing varieties.

Bacterial wilt occurs throughout the corn-growing sections of the United States but seldom is of any importance north of the Corn Belt proper. From Long Island to Virginia and westward the disease has caused the greatest losses to market gardeners, home gardeners, and canners.

The disease is caused by bacteria that develop in abundance in the leaf veins and in the water-conducting vessels of the stalks. Young sweet corn plants may wilt and die or may develop long wilted pale-green streaks in the leaf blades. These plants remain stunted, tassel prematurely, and produce no ears or only nubbins. Young dent corn plants are more resistant to wilt infection, but when the plants are in tassel they develop leaf streaks, which may be sufficiently abundant to blight the leaves and make the plants more susceptible to diplodia stalk rot.

Wilt bacteria may be carried over winter to a limited extent in infected seed. In this way they may be introduced into new areas or countries. The most important means of distribution, however, is by corn flea beetles. These beetles feed on diseased corn plants in the summer and fall, live over winter, and carry the wilt bacteria to the young corn plants in the spring as they feed on them. Later they spread the infection, and as new broods of beetles increase their numbers, they spread the infection still farther. Thus the disease becomes increasingly abundant as the season advances.

Recently developed early yellow sweet corn hybrids that are more or less resistant to wilt have largely replaced the early susceptible sweet corn varieties. Of the new wilt-resistant hybrids, Golden Cross Bantam is the most widely adapted and most generally used. Progress in breeding sweet corn for wilt resistance indicates promising possibilities for the development of wilt-resistant varieties and hybrids of dent corn.

The use of resistant varieties is the only practicable means of controlling bacterial wilt.

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# BACTERIAL WILT OF CORN

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BACTERIAL wilt is one of the most destructive diseases of corn, particularly in certain susceptible varieties. Sweet corn, in general, is more susceptible than field corn and, in sweet corn, the earlier, sweeter varieties are the most susceptible.

In some years and in certain areas, bacterial wilt causes almost total losses of early varieties of sweet corn, such as Golden Bantam. Canners of sweet corn in Maryland, Ohio, and other States who had specialized in Golden Bantam suffered such heavy losses that they eventually gave up Golden Bantam and for a number of years processed the later-maturing resistant varieties, such as Country Gentleman and Stowell Evergreen. In recent years, however, these canners have been replacing the late, wilt-resistant, white sweet corn varieties with the new resistant Golden Cross Bantam and other resistant yellow hybrids. The use of these new resistant hybrids has about solved the wilt problem in sweet corn, but in 1932 the disease, in a somewhat different form, began to menace field corn. In 1932 and 1933 wilt developed as a leaf blight on dent corn in Indiana and Illinois. Injury done by this leaf blight made the plants more susceptible to diplodia stalk rot. In 1938 and 1939 leaf blight again appeared on dent corn in the Central States and caused losses of as much as 20 percent in some of the new hybrids. These losses in dent corn have shown that bacterial wilt is important in field corn as well as in sweet corn.

## DISTRIBUTION OF THE DISEASE

Bacterial wilt was first found in sweet corn on Long Island in 1895 and now occurs throughout the corn-growing sections of the United States (fig. 1). It has been reported from Puerto Rico and South Africa and in recent years has been found in Mexico. In 1935 it was reported for the first time in Italy.

The disease occurs to some extent each year in the area from Long Island to Virginia and westward throughout the Corn Belt. It is in this area that the disease is most generally distributed and has caused the greatest losses to market gardeners, home gardeners, and

canners. The elimination of the early susceptible varieties in this area and the growing of resistant varieties and of new resistant hybrid sweet corn has greatly reduced the losses, particularly in epidemic years.

Throughout the Southern States so little early sweet corn is grown that the disease is important only in isolated fields.

The prevalence of wilt decreases from South to North, and it is only when the disease becomes abundant throughout the Central States that it is found very far north of the Corn Belt proper. About 1920 a careful search for wilt revealed none of this disease in North Dakota, Minnesota, Wisconsin, Michigan, northern New York, Vermont, New Hampshire, or Maine. In 1932 and 1933 the disease was

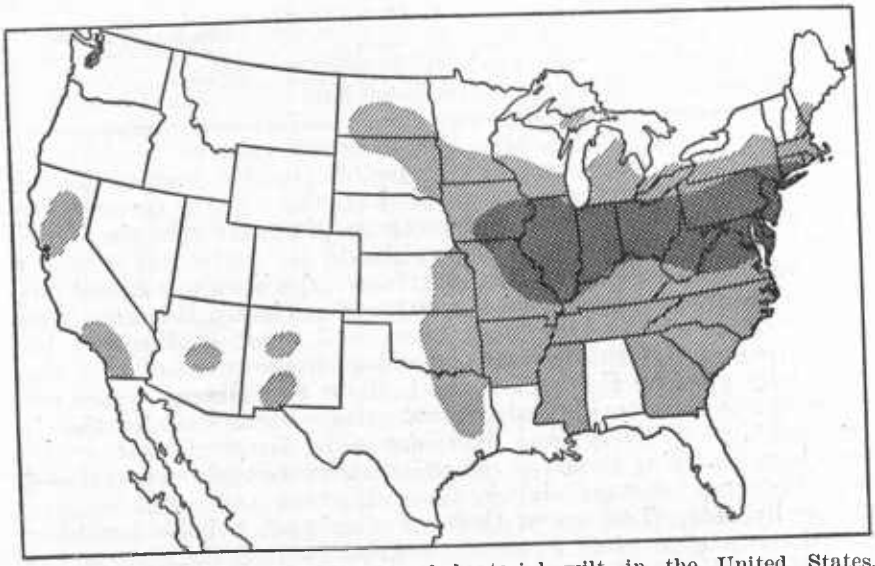

FIGURE 1.—Geographic distribution of bacterial wilt in the United States. Double shading indicates areas in which the disease is most destructive.

found in all of these States except Vermont. It caused some losses also in southern Ontario and was reported from the northern peninsula of Michigan. Since that time epidemics of bacterial wilt have become more of a menace to the early susceptible sweet corn grown in these Northern States. In the northern areas, however, losses usually are low and wilt epidemics rare.

## HISTORY OF WILT EPIDEMICS

For the past 40 years there have been intermittent outbreaks of bacterial wilt throughout the Central States. In the earlier years losses were local, but year after year the disease became more generally distributed and losses continued to increase because of the practice of growing early-maturing, very susceptible sweet corn varieties, such as Golden Bantam, in the States where wilt was prevalent. In years when losses were heavy, early infections were abundant on young

plants, and, as a result, many of these plants were stunted or killed. In the intervening years when wilt was less abundant, there was much less early infection. Instead, infection became abundant late in the season in the form of leaf lesions, which interfered but little with the growth of the sweet corn plants.

On Long Island from 1895 to 1897 entire crops were destroyed in some cases, and losses of 20 to 40 percent were frequent. In 1917 in Maryland wilt caused as much as 25-percent loss in some fields. In 1922 one canning company lost 50 to 60 percent of its 600 acres of Golden Bantam. In Ohio in 1918 losses of 10 to 30 percent were reported, and during succeeding years the disease caused serious losses to truck growers in northern Ohio, where early corn was grown for the roasting-ear market. By 1929 wilt was doing considerable damage even in southern Ohio, where more resistant varieties were grown. In Illinois and Indiana the disease at first was more general and destructive in the central and southern parts of these States, but in 1932 one canning company in northern Illinois estimated a loss of 30 percent on 500 acres and 10 to 15 percent on an additional 3,000 acres of Golden Bantam.

Following 1929 wilt became generally destructive on early susceptible varieties throughout the Central States, causing heavy losses in early varieties each year until, in 1932 and 1933, the most destructive epidemics on record occurred. Susceptible varieties in market gardens in Illinois were in many cases complete losses. Throughout Pennsylvania, Maryland, Virginia, and West Virginia, and on through the central corn-growing States, whose fields of early sweet corn were destroyed by the disease; and even the later more resistant varieties showed more infection than usual. For the first time in the history of the disease, infection on dent corn became sufficiently abundant to attract attention and cause losses, particularly in central and southern Illinois and Indiana.

In 1932 the disease developed to epidemic proportions in the southern counties of New York State. Over 300 acres of sweet corn in Rockland County were plowed under because of wilt. In Massachusetts, wilt was found all over the State, but the losses were not nearly so heavy as in States farther south. Wilt was reported for the first time in southern Ontario and spread up into central Michigan.

In 1933 wilt was found in central New York. In Massachusetts in that year spread of the disease and losses to growers were reported to be 5 to 10 times as extensive as in the previous year. In southwestern Maine and southern New Hampshire, where the disease had not been found previously, wilt was rather common and, in a few cases, destroyed early plantings. Wilt became general and destructive in 1933 in southern Ontario and was found in the northern peninsula of Michigan.

In 1934 there was a decided decline in the distribution and abundance of bacterial wilt. It disappeared from southern Canada, Maine, New Hampshire, and central New York; and in Massachusetts and Connecticut only traces were found. Early infections were rare or absent, and, although late leaf infections were common, losses were negligible. Throughout the Central States the growing of resistant varieties makes comparisons with previous years difficult, but the

disease was less abundant than in 1932 and 1933. By 1936 wilt had become definitely less destructive than for a number of years. It was not found in Massachusetts, and only light infection occurred in New Jersey, Pennsylvania, and Ohio. In Virginia susceptible varieties


FIGURE 2.—Rows of wilt-susceptible Gill Improved Golden Bantam sweet corn grown on the Arlington Experiment Farm, Arlington, Va., *A*, in 1936, when there was very little wilt early in the season; and *B*, *a*, in an adjacent part of the same field in 1937, when there was a mild wilt epidemic. *B*, *b*, Wilt-resistant Golden Cross Bantam.

produced a good crop (fig. 2, *A*) for the first time in several years. In 1936 early infections were very light throughout the Central States, but late leaf infections were abundant, and this contributed to a mild epidemic in 1937 (fig. 2, *B*, *a*).

## DESCRIPTION OF THE DISEASE

Bacterial wilt is a typical vascular disease. The bacteria develop in abundance inside the vascular bundles (water- and nutrient-

FIGURE 3.—Golden Bantam sweet corn heavily infected with bacterial wilt, showing some leaves with streaks, others wilted and top wilted, and the plants stunted.

conducting vessels) of stalks and leaves of infected plants. The symptoms on sweet corn are somewhat different from those on dent corn.

### SYMPTOMS ON SWEET CORN

Early sweet corn varieties are susceptible to infection throughout their growth. Young infected plants in the field often wilt as if

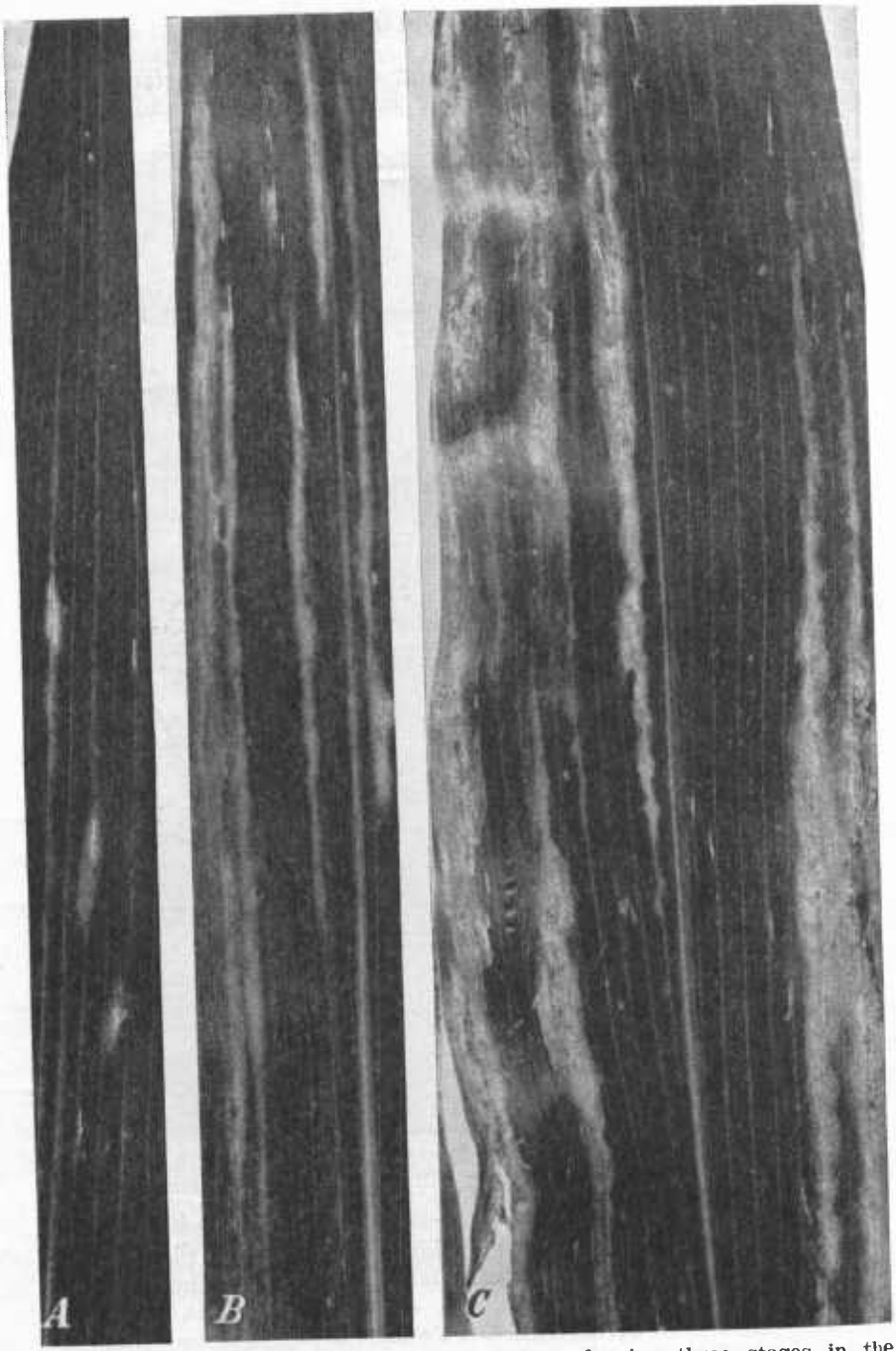


FIGURE 4.—Golden Bantam sweet corn leaves showing three stages in the development of wilt leaf-lesions following insect feeding injuries. *A*, Feeding injuries and beginning lesions on tip end of leaf; *B*, young developing lesions spreading along the veins; *C*, old lesions spreading toward stalk.

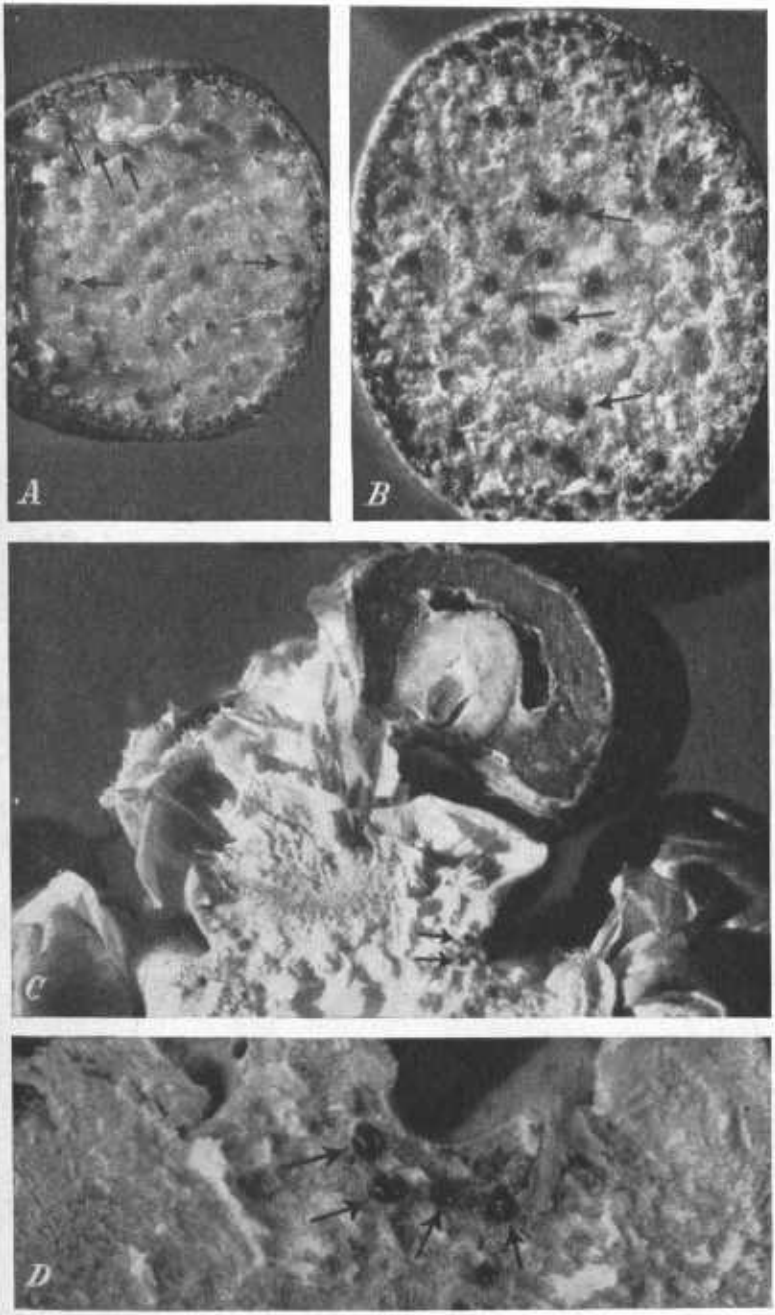


FIGURE 5.—Sections of stalks, shank, and cob of a susceptible inbred line of Golden Bantam sweet corn showing beads of bacterial ooze (arrows) on the cut ends of many of the vascular bundles of: *A*, Stalk (enlarged 4 times); *B*, ear shank (enlarged 4 times); *C*, base of cob (enlarged 4 times); and *D*, portion of *C* indicated by arrow (enlarged 10 times).

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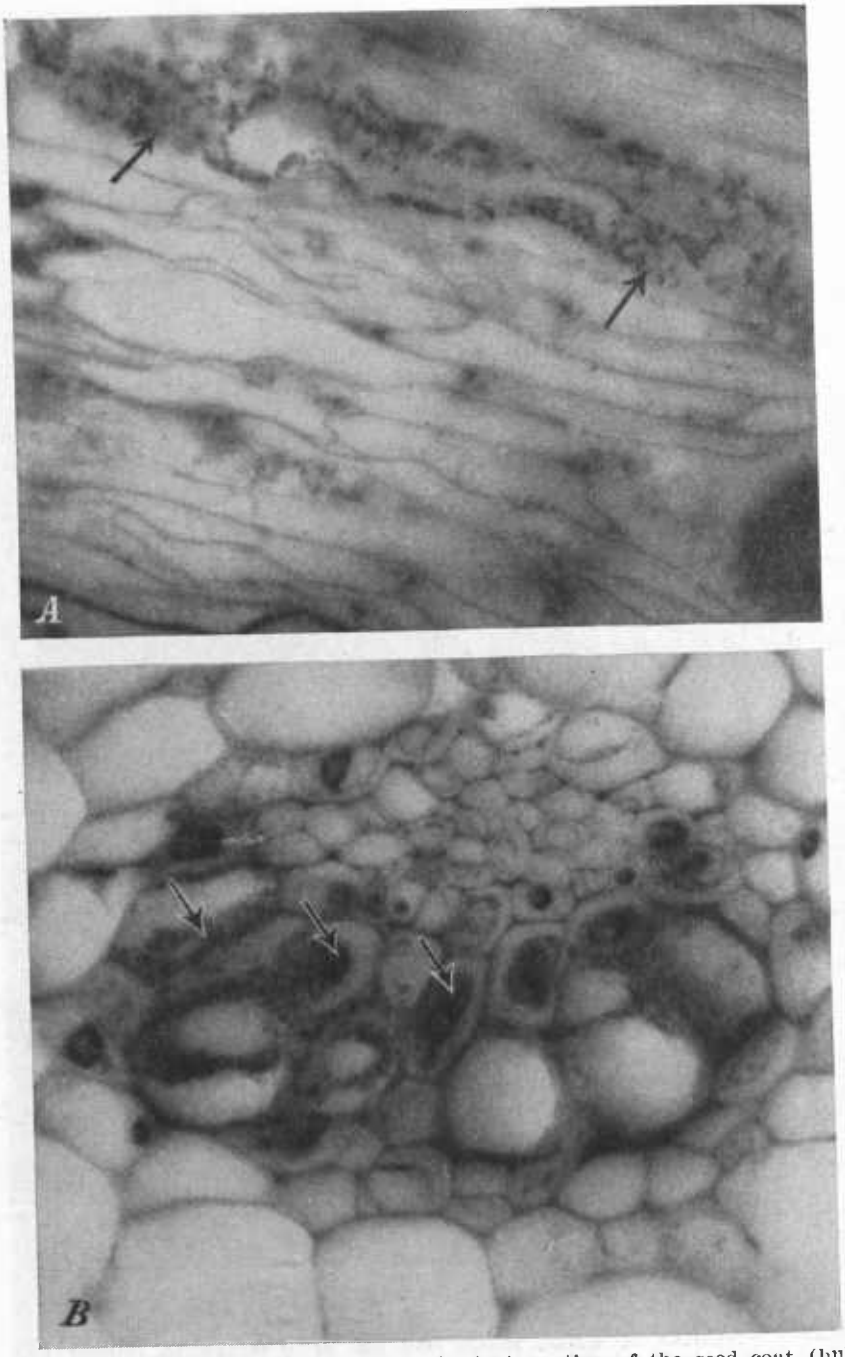


FIGURE 6.—Highly magnified sections of: *A*, A portion of the seed coat (hull) of a sweet corn kernel showing bacteria (arrows) between the cells; *B*, a portion of the base of an infected corn kernel showing bacteria (arrows) in the cells of a vascular bundle.

suffering from lack of water. The green leaves wilt and dry up one after another until the whole plant may wilt and die even though there is plenty of moisture in the soil. Young infected plants of susceptible varieties that do not wilt and die become stunted, tassel prematurely, and produce no ears or, at most only nubbins (cover page, right). As the plants grow larger, long, wilted, pale-green streaks develop in the leaf blades (figs. 3 and 4). These streaks start from insect-feeding injuries, usually on the tip half of the leaf (fig. 4, *A*), and may spread along the veins back into the stalk (fig. 4, *B* and *C*). The vascular bundles of the stalks may become so filled with bacteria that when the stalks are cut, masses of the bacteria ooze out as yellow, viscid beads on the cut ends of the stalks and shanks (fig. 5, *A* and *B*). Bacteria also may spread into the tissues along the vascular bundles of the stalks and form cavities in the pith. The bacteria may occur in nearly all parts of the plant—roots, stalks, leaves, sheaths, tassels, husks, ear shanks, cobs, and kernels (fig. 5, *A*, *B*, *C*, and *D;* fig. 6, *A* and *B*). Bacteria may come out in tiny drops on the inner surfaces of the husks (fig. 7) and become smeared over the kernels. They also spread from the cob into the interior of the kernels (figs. 5, *C* and *D*, and 6).

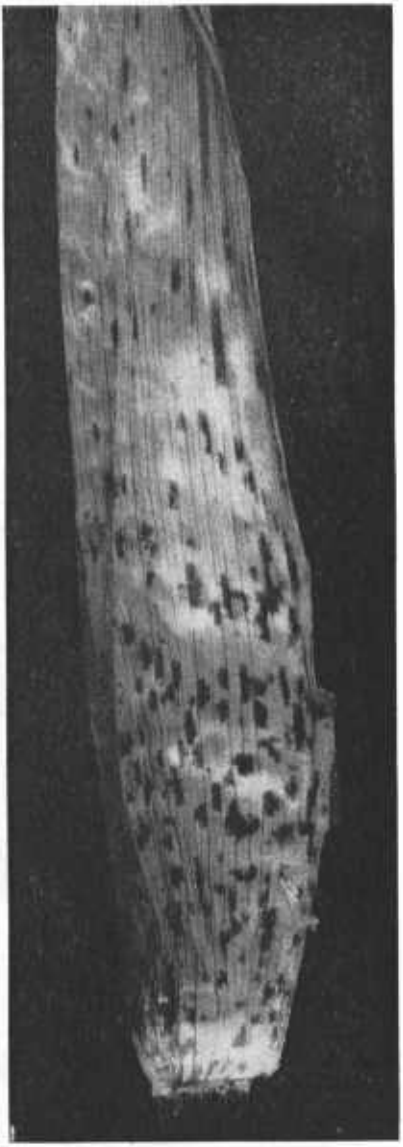

FIGURE 7.—Sweet corn husk showing bacterial wilt spots from which bacteria oozed out in tiny drops.

## SYMPTOMS ON DENT CORN

Young plants of field corn are more resistant to wilt infections than are those of sweet corn. In spite of insect-feeding injuries (fig. 8) on young plants of yellow dent corn, few become infected and very few become stunted. The long streaks in the leaves of young plants that are so common in susceptible sweet corn (figs. 3 and 4) are not common on dent corn varieties. It is only after the dent corn plants are in tassel that large numbers of leaf streaks begin to develop. These leaf streaks may become so abundant as to blight the leaves. This leaf blight or streaking spreads

FIGURE 8.—Plant from an inbred line of yellow dent corn showing abundant feeding injuries of the corn flea beetle but no wilt lesions, whereas susceptible sweet corn plants grown nearby showed abundant infections.

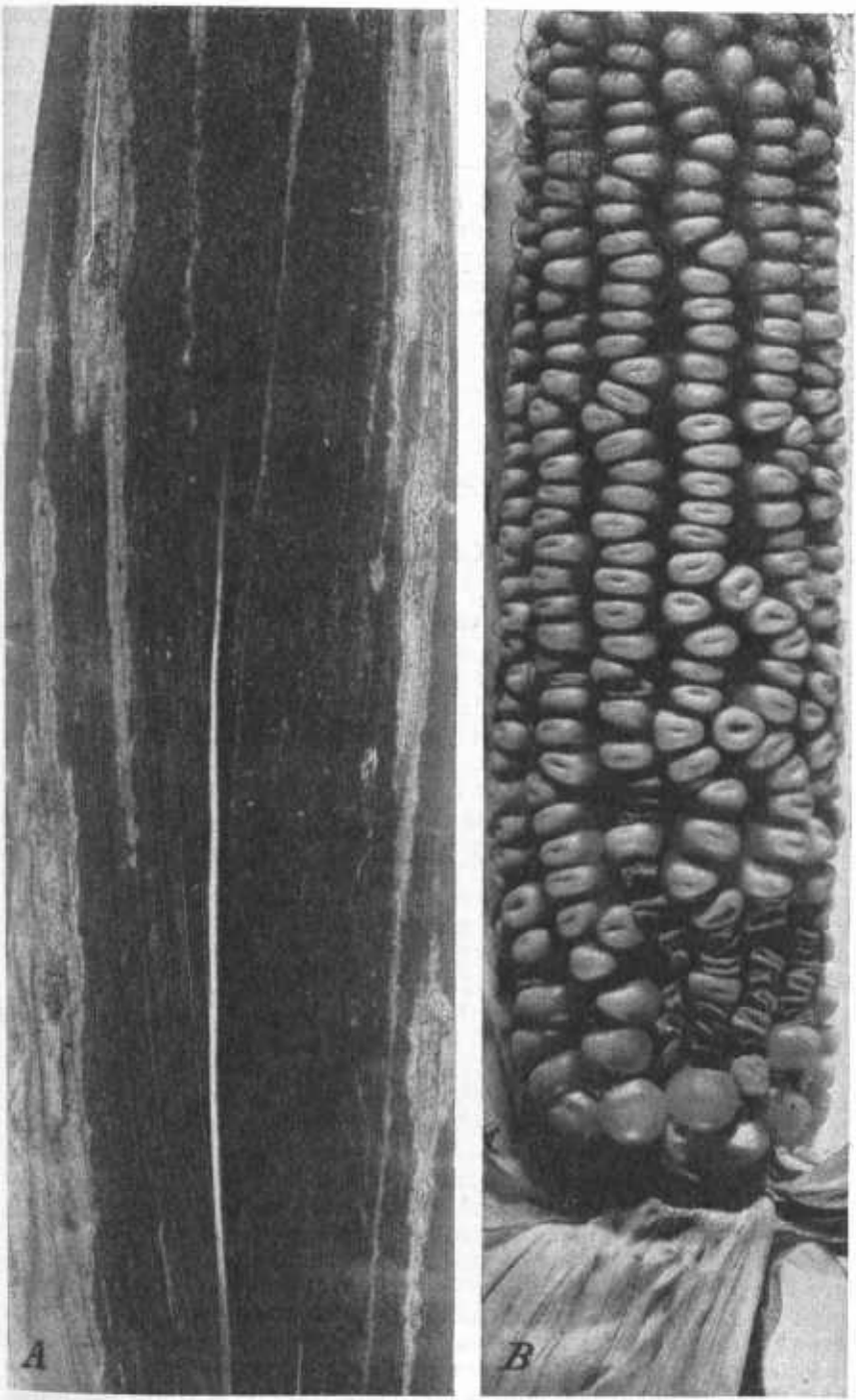


FIGURE 9.—*A*, Leaf of dent corn showing bacterial streaks (leaf blight); *B*, ear of dent corn showing shriveled kernels infected with wilt bacteria.

very rapidly over the field and is the characteristic form of infection on dent corn (fig. 9, *A*). In dent corn, infections from these leaf lesions usually do not spread back into the stalks; therefore, when the stalks are cut, bacterial ooze is likely to be much less evident than in susceptible sweet corn.

On susceptible varieties of dent corn the light-green to yellow streaks in the leaves may spread rapidly along the leaf veins. When the streaks come together and the whole leaf becomes involved, the leaf dies and dries up. This premature dying of leaves while the stalks remain green gives the plants the appearance of having been frosted. On resistant field corn the leaf streaks are less abundant, enlarge very slowly, and may never become more than oval spots 1 or 2 inches long. Destruction of a considerable part of the leaf area by wilt streaks not only seriously interferes with the manufacture of food for supplying the developing ears but also makes the stalks more susceptible to attack by diplodia stalk rot, which in turn weakens them so that they break over badly in storms. Dent corn ears also may become infected (fig. 9, *B*), but this is less common than in the more susceptible varieties of sweet corn.

## CAUSE OF THE DISEASE

Bacterial wilt is caused by a species of bacteria known as *Aplanobacter stewarti* (E. F. Smith) McCulloch. Individual bacteria are microscopic, nonmotile rods less than one twelve-thousandths of an inch long. These bacteria get into the corn plants through wounds in the leaf tissue made chiefly by the feeding of corn flea beetles (fig. 10). Once inside the plant, the bacteria may multiply until they fill the water vessels of the veins of the leaf (fig. 11, *A* and *B*), spread through the veins into the stalk, and fill many of the water vessels in the vascular bundles (fig. 5, *A* and *B*). In this way the bacteria plug up the water vessels and prevent the plants from getting water and food materials. These plants wilt and die or become stunted, depending on the number of water vessels that become plugged up. The bacteria may spread also through the stalk into the tassel and ear, and the infection may become general throughout the corn plant.

## HOW WILT BACTERIA ARE CARRIED OVER WINTER

Corn plants may become infected either through the seed or through the feeding injuries of insects carrying the bacteria, but apparently few if any plants become infected through the soil. The bacteria that cause bacterial wilt occasionally may live over winter in soil, manure, or overwintered cornstalks, but it has not been demonstrated that plants ever become infected from such soil or crop refuse. Plants grown in infested soil have remained free of the disease when they were covered with cages to keep out insects. Experimental plants grown in the greenhouse in soil from fields that had produced heavily infected plants for 5 years have shown no infection. Even when grown in soil artificially inoculated with bacteria or overwintered, infected stalks, corn plants have not become infected unless the roots have been artificially wounded so that the bacteria could get inside. As root wounding is necessary for such transmission, it is probable

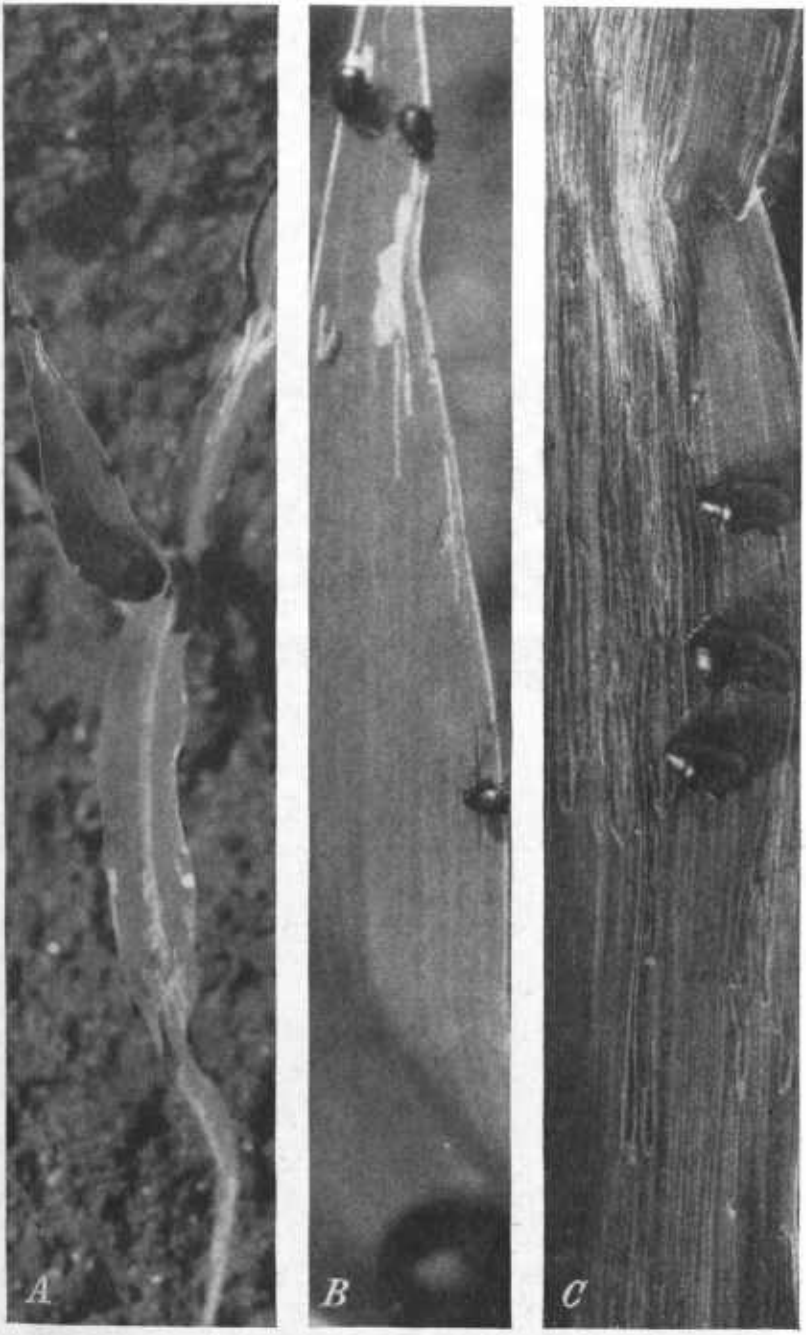


FIGURE 10.—Sweet corn leaves on which corn flea beetles are feeding and the feeding injuries produced. *A*, Top view of young plant in the field, with three beetles feeding on the uppermost leaf (natural size); *B*, same leaf and beetles enlarged four times; *C*, portion of another leaf showing conspicuous feeding channels (enlarged eight times).

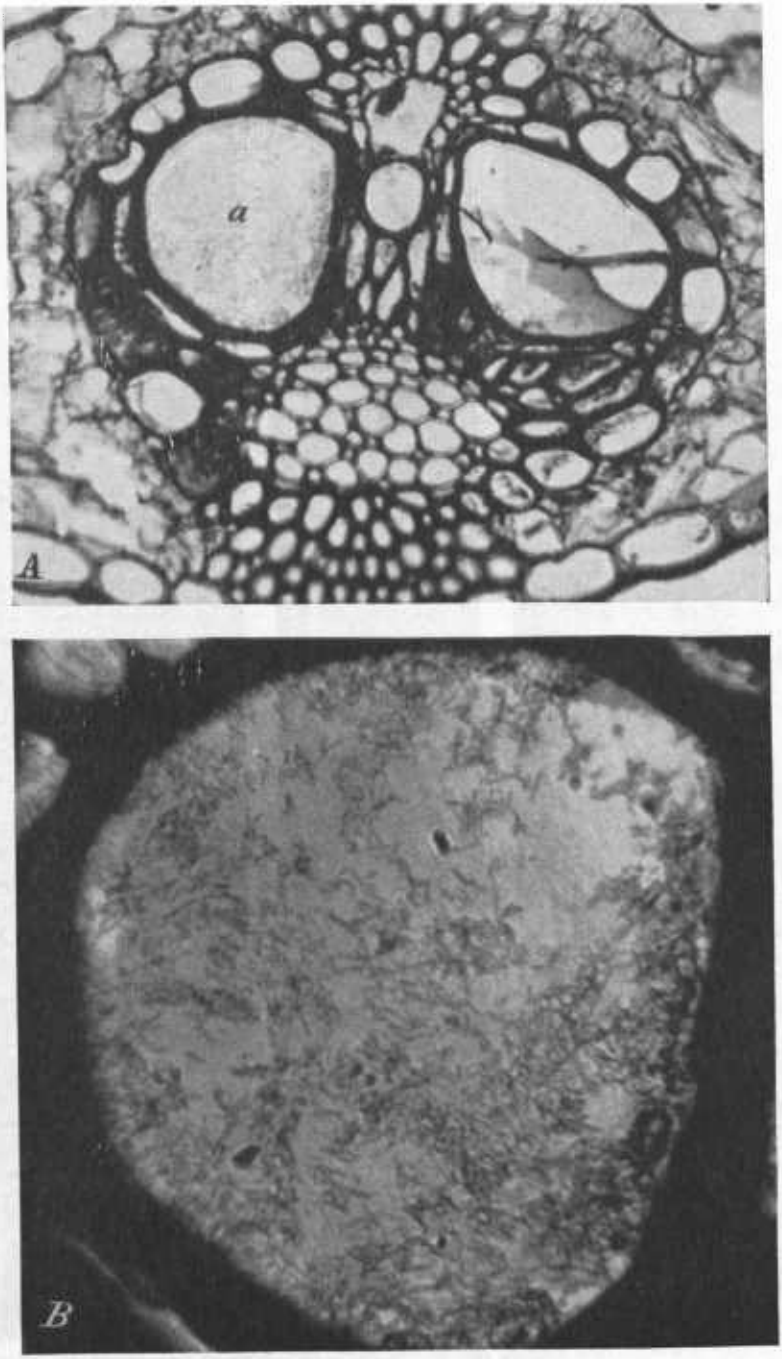


FIGURE 11.—*A*, Cross section of a vein of a leaf of dent corn as seen, greatly enlarged, under the microscope. One of the large water vessels (left), which is shown still more highly magnified in *B*, is filled with bacteria. (*A*, Magnified 350 times; *B*, magnified 1,100 times.)

that overwintering of the wilt organism in the soil is of negligible importance.

Wilt bacteria may pass from the vascular bundles of the stalk through the shank and cob into the corn kernels (figs. 5, *C* and *D*; 6; and 9, *B*) and remain alive there for several months. It is probably from such infected seed that the disease is introduced into previously uninfested regions or countries. However, when such infected kernels are planted, only about 2 percent of the plants grown from such infected seed become infected.

Although the limited seed transmission of the wilt bacteria has been known for many years, this source of infection has never accounted for the abundance of the disease early in the season on young, susceptible sweet corn plants, even when grown from infected seed. Furthermore, young, susceptible sweet corn plants grown from uninfected seed likewise become abundantly infected early in the spring. It was, therefore, of special importance to find, recently, that the wilt bacteria overwinter abundantly within the bodies of the corn flea beetle (*Chaetocnema pulicaria* Melsh),[1] and that this insect carries them to the young corn plants in considerable abundance in the spring soon after the corn comes up. The adult beetles, as the weather becomes warmer in April and May, come out of hibernation and begin feeding on growing vegetation. They prefer corn and, hungry after a winter's fast, begin feeding voraciously on the young corn plants soon after the corn is up (fig. 10, *A* and *B*). The beetles feed chiefly on the under surfaces of the small seedling leaves and eat out the leaf tissue between the veins in long, clean channels (fig. 10, *C*). These feeding injuries, which show as fine white lines, may be less than a thirty-second of an inch wide and from one-fourth inch to more than one-half inch long. Several parallel channels may be formed by continued feeding (fig. 10, *C*). It is through these feeding channels that the wilt bacteria, carried by the beetles, get into the injured corn leaves. When infection takes place, the areas around the feeding injuries take on a lighter green color (fig. 4, *A*). Such areas may increase rapidly in length along the veins and have more or less indefinite and irregular margins (fig. 4, *B*). As the bacteria multiply and spread within the corn leaves, these first, or primary, wilt streaks may soon turn yellow and die through the center and thus form dead, brown streaks with living, light-green to yellow edges (figs. 4, *C*, and 9, *A*); or the infection may extend rapidly back into the young plant and cause long greenish-yellow leaf stripes, and then invade the stalk and either kill or dwarf the entire plant (fig. 3).

Extensive studies have shown that the wilt bacteria overwinter almost exclusively in the corn flea beetle in areas where bacterial wilt occurs, and indications are that infections on young, susceptible sweet corn plants are most abundant when there is evidence of a greater amount of early feeding by overwintered beetles.

## HOW WILT IS SPREAD DURING THE CORN-GROWING SEASON

In the spring after the first young corn plants have become infected through the feeding injuries of overwintered infested corn flea beetles,

[1] The insect investigations referred to in this bulletin were conducted in cooperation with the Bureau of Entomology and Plant Quarantine.

other corn flea beetles, previously uninfested, feed on the infected plants and become infested. They then carry the wilt bacteria to other corn plants on which they feed. More corn plants become infected, more beetles carry the wilt bacteria, and thus the disease becomes more general in a locality as the season advances. These infested beetles may also migrate or be carried by air currents considerable distances to other sections where wilt has not developed.

When the beetles have once become infested with the wilt bacteria, experiments have indicated that they carry them inside their bodies and are able to transmit them to healthy corn plants as long as those beetles live. Furthermore, increasing numbers of the beetles from new broods that develop during the summer feed on infected corn plants and thus increase still further the number of beetles that carry the wilt organism as the season advances. Although only about 10 to 20 percent of the beetles coming out of hibernation in the spring may carry the bacteria, by midsummer, in some localities, as many as 75 percent of the beetles feeding on infected corn often carry the bacteria internally. In Virginia, susceptible sweet corn usually shows the greatest number of infected plants and also the heaviest infection about the middle of July.

Relatively few wilt infections develop on young dent corn plants, despite heavy feeding of corn flea beetles (see fig. 8). After the plants are in tassel, however, the leaves of dent corn apparently become less resistant to the wilt bacteria. Leaf infections begin to appear on the dent corn plants in late July and early August, when the beetles are most abundant and the largest numbers are carrying the wilt bacteria. The amount of leaf infection and of resulting leaf blight in a corn variety depends both upon the number of infested beetles and upon the degree of susceptibility of the corn variety. Infections on the leaves of susceptible dent corn plants (fig. 9, *A*) may become so abundant in August and September that entire leaves may die and dry up before the ears have matured, making the plants look as if they had been injured by frost.

## VARIETAL RESISTANCE TO WILT

Bacterial wilt may occur in sweet, flint, flour, and dent corn and popcorn. In general, sweet corn is the most susceptible and dent corn the most resistant. Usually the early-maturing varieties of each type of corn are more susceptible than the later-maturing varieties. Particularly in open-pollinated varieties of sweet corn, susceptibility to wilt is closely associated with earliness.

Such early varieties of sweet corn as Extra Early Bantam, Golden Bantam, Golden Early Market, Golden Gem, Golden Sunshine, Gill Improved Golden Bantam, Gill Early Market, and Gill Early Golden, which have been favorites because of their short growing season and high quality, have suffered heavy losses because of susceptibility to wilt. Because of this, canners in Maryland, Ohio, and other States were forced to replace Golden Bantam with later-maturing, more resistant varieties. Whipple Yellow and Spanish Gold, slightly later varieties, have been less susceptible but in some years have been severely injured by wilt. In New Jersey in 1933, Extra Early Golden Bantam, open-pollinated Golden Bantam, and Whipple Yellow, grown

in the same field, at harvest showed 61 percent, 52 percent, and 20 percent, respectively, of dead stalks.

Later-maturing white varieties such as Stowell Evergreen, Vanguard, Howling Mob, Long Island Beauty, and Country Gentleman are much more resistant to wilt. Some of these varieties have shown losses from wilt of only 5 to 10 percent when early Golden Bantam strains were a complete loss.

New, early, yellow sweet corn hybrids, which are more or less resistant to wilt, have largely replaced the less desirable white sweet corn varieties in the canning industry during the past 10 years. Unfortunately some of the new yellow hybrids are somewhat susceptible to wilt. In 1937 in New Jersey, Canada Gold and Bancross suffered losses in yield up to 99 percent. Losses in Golden Cross Bantam,

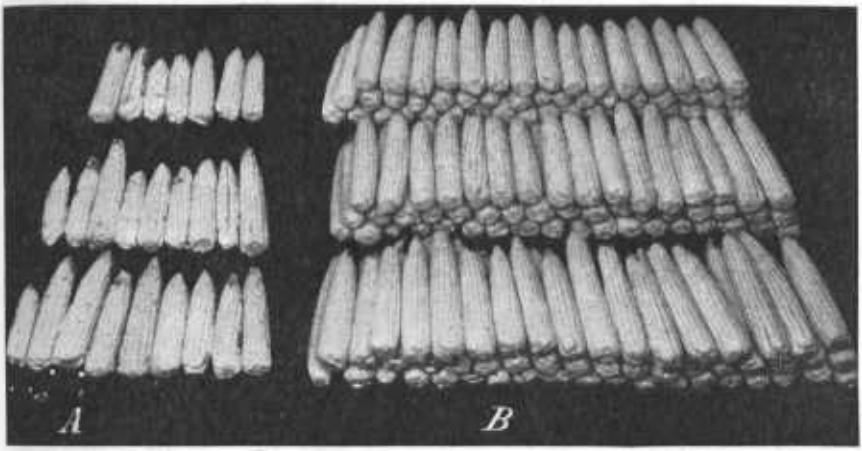


FIGURE 12.—Yields of susceptible and resistant sweet corn grown in adjacent single rows 130 feet long at Arlington, Va., in 1937. *A*, Wilt-susceptible Gill Improved Golden Bantam, 25 marketable ears; *B*, wilt-resistant Golden Cross Bantam, 153 marketable ears. In 1936, when there was very little loss from wilt, yields from the same length of rows were Gill Improved Golden Bantam 103 ears and Golden Cross Bantam 128 ears.

Tendergold, Spancross, Whipcross, and Marcross were comparatively slight although infection was common. These new hybrids may show streaking of the leaves, but the bacteria do not get into the stalk sufficiently to interfere with the intake of water and accordingly with growth and development of the plants. In years of moderate wilt these hybrids may suffer 1 to 2 percent reduction in yield as compared with 30 to 40 percent in Golden Bantam.

Of the new wilt-resistant hybrids, Golden Cross Bantam is the most generally used and also is the most widely adapted. It was released during the wilt epidemic of 1932 and 1933, and its success (figs. 2, *B*, and 12, *B*) in the canning and roasting-ear industries has greatly stimulated the development of other wilt-resistant hybrids. In New Jersey in 1933 and again in 1937, Golden Cross Bantam was the most resistant to wilt of 20 early and medium-early yellow sweet strains tested. In Illinois in 1933, Golden Sunshine suffered a total loss and Whipple Yellow a 60-percent loss, whereas Golden Cross Bantam showed only a 20-percent loss. In 17 trials in market gardens

in different parts of Indiana in 1933, commercial Golden Bantam averaged 40 percent infected plants; Top Cross Bantam, 22 percent; and Golden Cross Bantam, only 8 percent. In 20 plantings in Pennsylvania, in 1933, Golden Cross Bantam averaged less than 1 percent


FIGURE 13.—Two yellow dent inbred lines at Bloomington, Ill., in 1931. *A*, Wilt-resistant; *B*, wilt-susceptible.

infection, whereas all the plants of Golden Early Market were killed by wilt before they were 2 feet high. In the Northeastern States other resistant early hybrids such as Spancross and Sencross and later hybrids such as Whipcross, as well as Golden Cross Bantam, are being grown extensively and the elimination of the open-pollinated suscep-

tible varieties is greatly reducing losses to growers even in years of heavy wilt. In the Middle West, Indigold, Purgold, and other resistant hybrids are being grown. Earlier resistant hybrids are being developed at experiment stations throughout the corn-growing States, but as yet no very early, highly resistant, yellow sweet corn has been developed.

Popcorn varieties also show differences in susceptibility to wilt, although information on them is very limited. Black Beauty, Tom Thumb, Bear Foot, and Japanese Hull-less have been reported to be very susceptible and South American and Sunburst to be resistant.

The early maturing flour corns such as Mandan Flour, Mandan White and Yellow, Shoshoni, Soperton, and Winnebago Mixed appear to be very susceptible to wilt. Others such as Blackfeet, Hopi White, Potawatomi, Shawnee, and Seminole are moderately resistant; and Yuma Yellow, Arapaho, and Five Tribes have been resistant.

The early varieties of flint corn from the Northern States are very susceptible to wilt, whereas the late strains from the Southern States are resistant. Heavy losses sometimes occur when the northern strains of flint corn are grown in the Corn Belt proper or in epidemic years when the disease spreads into the northern border States. Infections of 100 percent in Gehu, 40 percent in Square Flint, and 20 percent in Longfellow and King Phillip have been reported. Infections of 85 percent in flint corn have been reported from Pennsylvania and West Virginia. A 50-percent loss was reported in a field near Cedar Rapids, Iowa.

Dent corn is the most resistant type, but, as in sweet corn, the early varieties usually are more susceptible than the later ones. Slight infections have been reported on dent corn for 20 years, but, until recently, losses from wilt have been considered of minor importance. Very little information is available on the exact relative resistance of the varieties. Losses of 2 to 5 percent were reported in Ohio in 1926, and 2 to 8 percent in 1933 in open-pollinated varieties. Most of the locally adapted strains in the Corn Belt have been resistant to general infection, but the epidemic of leaf blight in 1932 and 1933 materially weakened the plants and apparently made infected plants more susceptible to diplodia stalk rot. Since 1930 stalk infection and leaf blight have taken increasing tolls, particularly in certain dent corn hybrids. Experimental plots of inbreds and hybrids in different parts of the Corn Belt have shown conclusively that some inbreds and hybrids are resistant, whereas others are susceptible to wilt (fig. 13).

Although the exact relative differences in resistance of dent corn inbreds and hybrids have not yet been determined, the progress made in breeding sweet corn for wilt resistance indicates promising possibilities for the development of wilt-resistant varieties and hybrids of dent corn.

## EFFECT OF WEATHER ON WILT DEVELOPMENT

Weather records for the period from 1929 to 1936 appear to offer some explanation for the marked differences in wilt from season to season. A series of mild winters in the Central and Northern

States preceded the wilt epidemic of 1932 and 1933. Winter temperatures from 1930 to 1933 were 2° to 10° above normal throughout the Corn Belt and the Eastern States; and the winter of 1932–33 was particularly mild in New England. February 1934 was very cold, with temperatures from 2° to 12° below normal throughout the eastern part of the United States. Following this winter, bacterial wilt almost disappeared from the northern border States and became less abundant in the Central States. In Virginia, where wilt was very abundant, the one cold winter was insufficient to bring about a decided change. In 1936, after an unusually cold winter for Virginia, there was very little early infection. Later in the season, however, leaf infection became general as new broods increased the number of corn flea beetles, but this general infection was too late to interfere materially with the growth of the sweet-corn plants. Then, for the first time in several years, a good crop of marketable ears of Golden Bantam sweet corn was harvested at the Arlington Experiment Farm, Arlington, Va. (fig. 2, *A*). Thus, in the Northern States, where wilt is less abundant and winter temperatures are lower, wilt apparently can be wiped out by one severe winter. In sections farther south, however, where wilt is more destructive and winters less severe, a series of cold winters apparently is necessary to cause decided decreases in wilt. On the other hand, a series of mild winters tends to build up wilt to epidemic proportions.

## CONTROL OF WILT

The use of resistant varieties is the only practicable means of controlling bacterial wilt. Varietal differences in susceptibility or resistance to wilt in both field and sweet corn make it possible to select resistant inbreds and thus to develop hybrid corn resistant to bacterial wilt. Wilt epidemics of past years have greatly stimulated the work of developing wilt-resistant corn hybrids. Agricultural experiment stations, seed companies, and canners are now producing new sweet corn hybrids not only resistant to wilt but also high in yield and quality and, in some cases, of wide adaptability. Probably the most widely grown wilt-resistant sweet corn hybrid is Golden Cross Bantam, developed by Glenn M. Smith, of the United States Department of Agriculture, in cooperation with the Purdue University Agricultural Experiment Station. This hybrid is resistant to early infection, and the leaf lesions that develop after the plants have reached their growth interfere little if at all with the development of the ears (fig. 12). One of its outstanding characteristics is its wide adaptability to different soils and climates. It is, however, too late for the earliest market, but for canning purposes it is the most widely used yellow sweet corn. The parents of this cross are being used in other sweet corn crosses, and it is possible that an earlier hybrid of equal quality, yield, and adaptability as well as resistance to wilt may be developed. Lists of promising new sweet corn hybrids adapted to certain localities may be obtained from experiment stations or seedsmen. A number of experiment stations maintain seed true to type which is available to commercial growers.

The testing of dent corn inbreds and hybrids for resistance to wilt has been begun. The production of resistant hybrids will undoubtedly follow much the same course as in sweet corn, and good dent corn hybrids superior to open-pollinated varieties not only in yield, quality, and adaptability but in resistance to bacterial leaf blight will be developed. At present less is known of the resistance or susceptibility of strains of dent corn than of sweet corn, but the development of resistant strains is the only practicable method of control for bacterial leaf blight of dent corn.

Bacteria may remain alive from one season to another inside the seed and are not destroyed by surface seed treatment. Dry-heat treatments have been tried but cannot be recommended as yet. Seed treatments of any kind are of little value except to prevent the introduction of the disease into new countries or areas where bacterial wilt is not known to occur. Where the disease has occurred previously, transmission through the seed is responsible for so small a part of the field infections in the spring that it is of no practical importance. Seed treatments do not protect the plants from infection through feeding injuries of corn flea beetles, which is the source of most of the field infections. Disease-free seed from sections where wilt does not occur also is no insurance against wilt. On the contrary, plants from seed grown in Maine, where wilt seldom occurs, have been more susceptible to wilt than plants of the same variety from seed grown in Maryland, where wilt is prevalent.

At present no practicable control measures are known for the corn flea beetles, which carry the wilt bacteria over winter and spread them during the growing season.

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